

Simulation of Controller Pilot Data Link Communications over VHF Digital Link Mode 3

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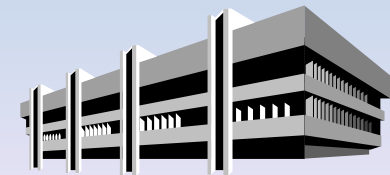
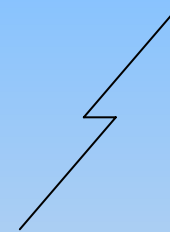
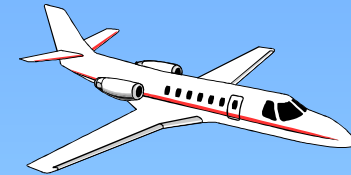
Analex Corporation
Cleveland, Ohio

Funded by the Advanced Communications for Air Traffic Management project at NASA. The AC/ATM project is tasked with researching systems to provide the improved performance and increased capacity required for future air traffic management concepts.

Objectives:

- To determine the impact of Controller-Pilot Data Link Communications traffic loads on the VDL Mode 3 subnetwork in the en route domain.
- To determine the delay CPDLC messages experience from the VDL Mode 3 subnetwork

- VHF Digital Link (VDL)
- Provides reliable data communication with an acknowledged connection-less data link protocol
- Supports voice and data communications
- Medium access by Time Division Multiple Access (TDMA)
- Uses the Aeronautical VHF Band (118 - 137 MHz)
- D8PSK modulation, 31.5 kbps data rate



Standard range configurations

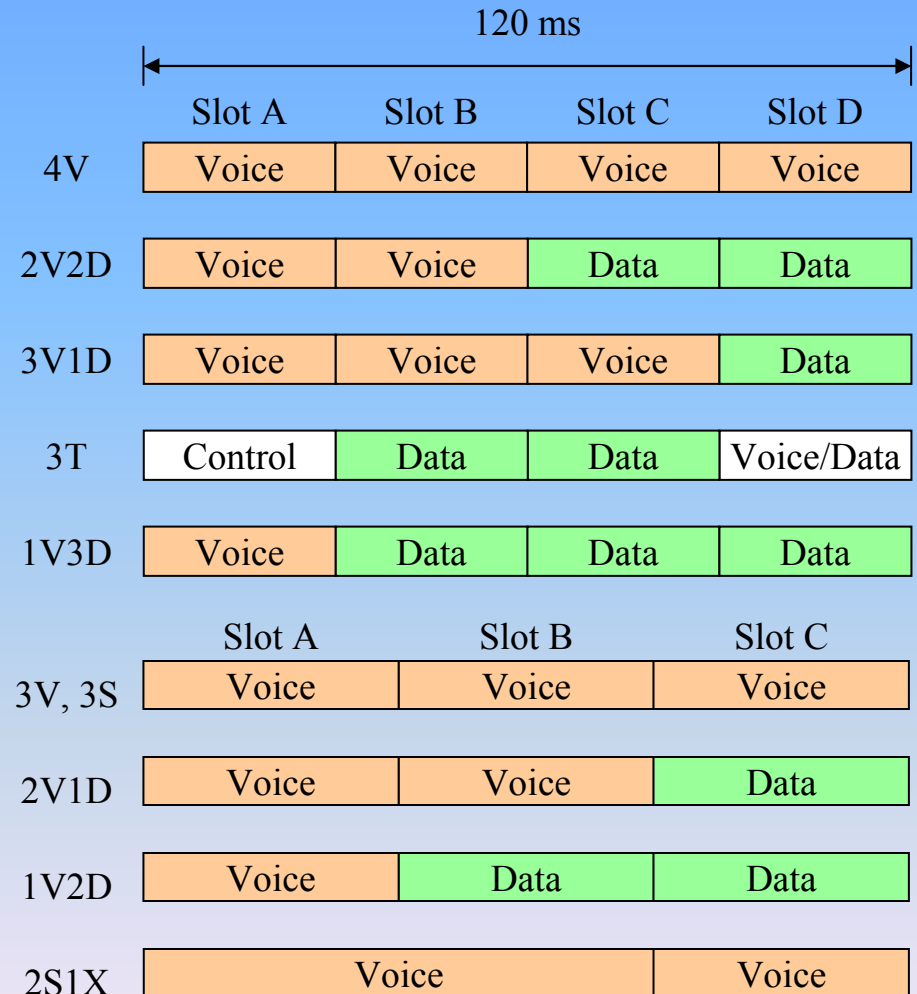
- 4 30 ms slots per frame
- Up to 200 nautical mile range

Extended range configurations

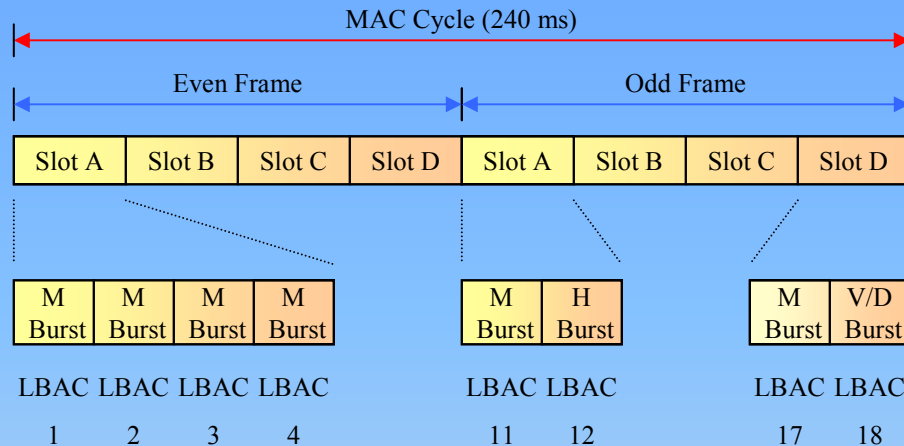
- 3 40 ms slots per frame
- Up to 600 nautical mile range

In this study we look at 3T only; future work will consider other configurations

- 2V2D
- 3V1D



VDL Mode 3 (3T)



Slot A – Management

Slot B and C – Data

Slot D – Voice or Data

Composed of 18 Logical Burst Access Channels (LBAC)

M – Management

H – Handoff check

V/D – Voice or Data

In both frames, Slots B and C are the same as Slot D

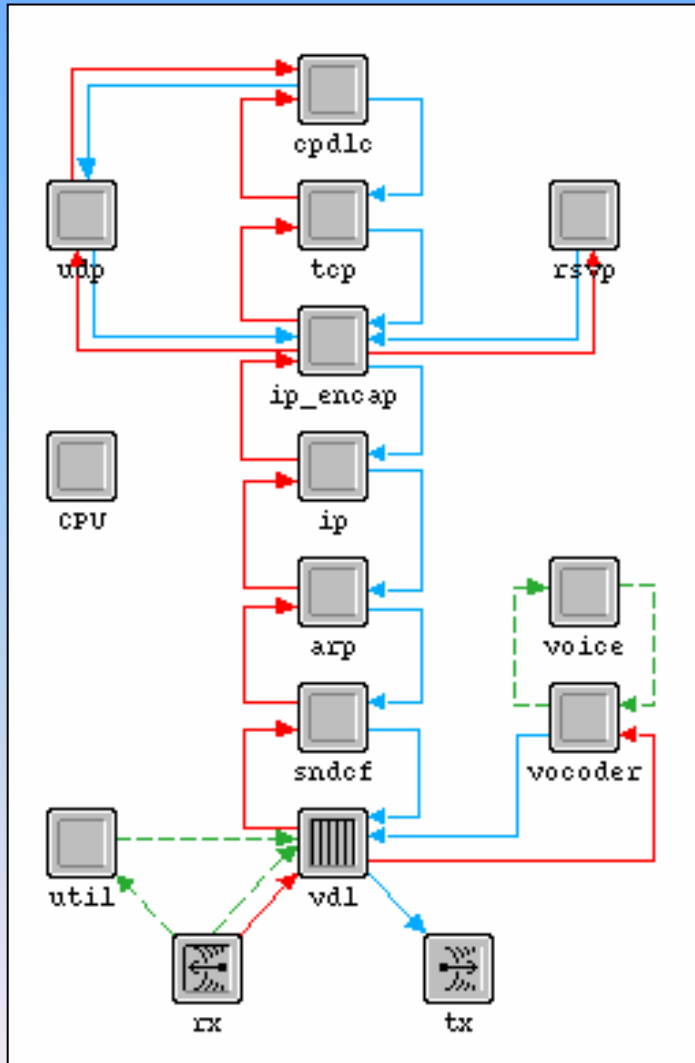
- Protocol supports up to 180 aircraft
- Each data slot can contain 496 bits of data
- Theoretical maximum data throughput: 12.4 kbps
- Useful in situations which contain predominately data and occasional voice

Controller-Pilot Data Link Communications replaces voice commands and requests with small digital messages

- Uses Abstract Syntax Notation 1 (ASN.1) format

Benefits of CPDLC:

- CPDLC messages are more efficient than analog or digitized voice
- Error-checking is incorporated into transmission of messages, ensures messages are received accurately
- Text display of messages, allows messages to be reviewed at a later time without repetition



Aircraft and ground node model

Combination of OPNET-supplied and custom models

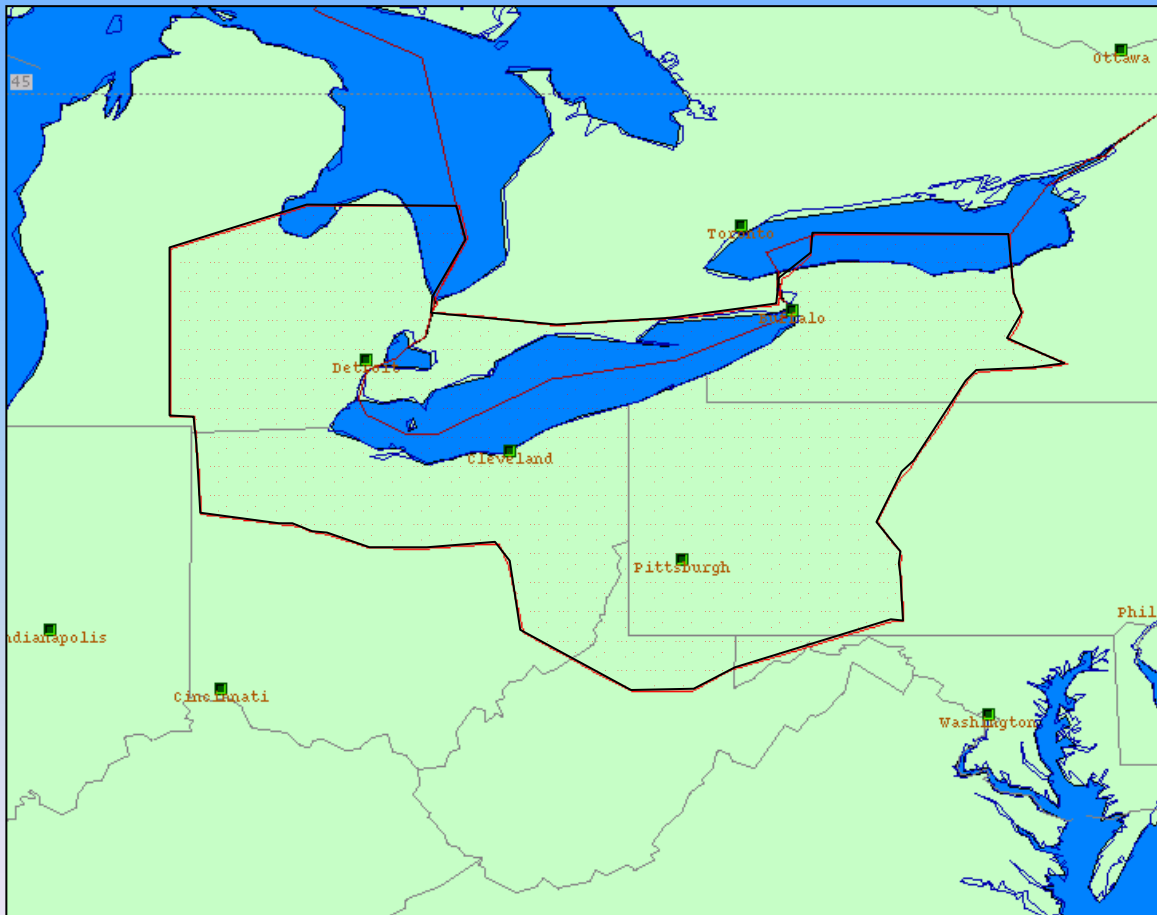
Uses IP protocol stack in place of ATN protocols

Models CPDLC by statistical generation of message sizes and inter-arrival times

Models VDL MAC and DLS sublayers in detail

Does not simulate aircraft or ground-based networks

Flight Traffic Data



Actual flight traffic data from Cleveland Air Route Traffic Control Center (ZOB ARTCC) used for simulations

Data covers all flights that pass through ZOB from takeoff to landing

Data taken over a 24 hour period

CPDLC Messages

Priority	Uplink Size (bits)	Downlink Size (bits)	Mean Inter- Arrival Time (s)
High	72	12	2850
High	13	12	5700
High	68	12	5700
Medium	691	690	774
Medium	36	676	5700
Medium	13	12	5700
Low	13	120	387
Low	300	43	2850

Messages are based on RTCA documents

Inter-arrival times are converted from messages per flight and messages per sector to messages per second

Times based on average time per sector/flight

2 simulations performed

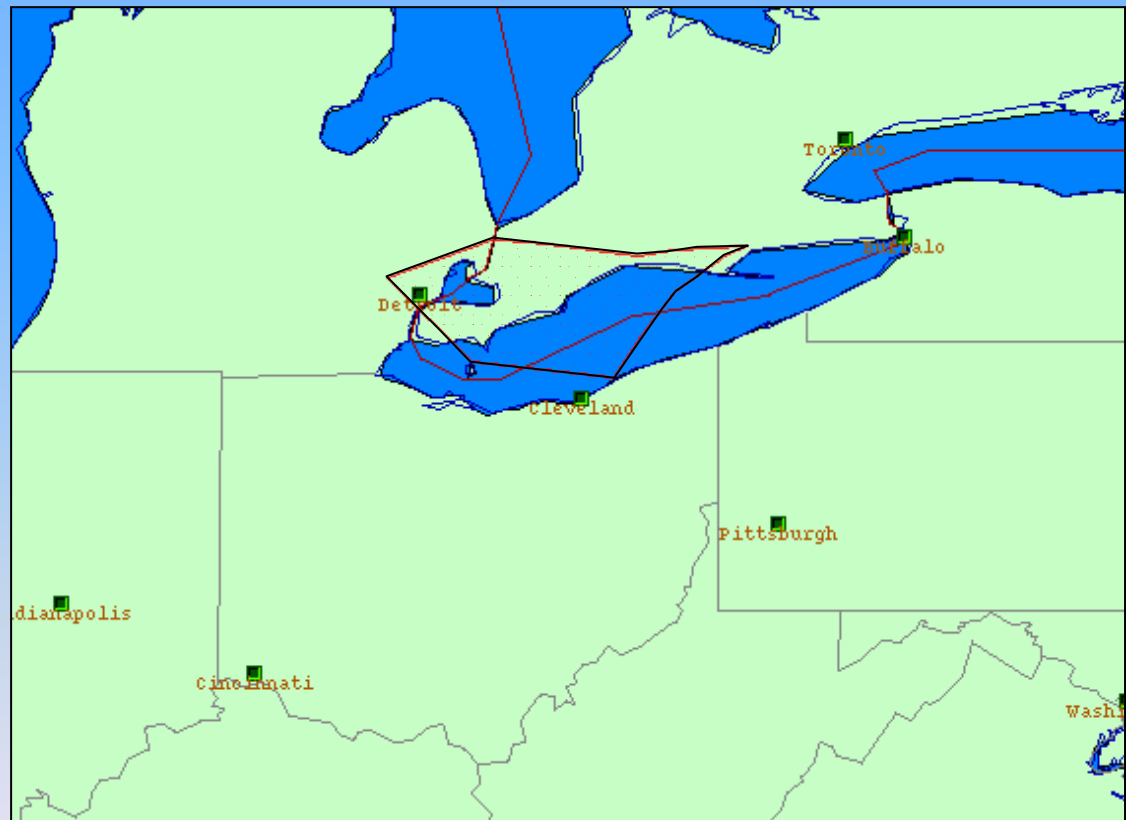
- Sector-based CPDLC communications
- Range-based CPDLC communications

Subnetwork delays compared to the VDL MASPS requirements

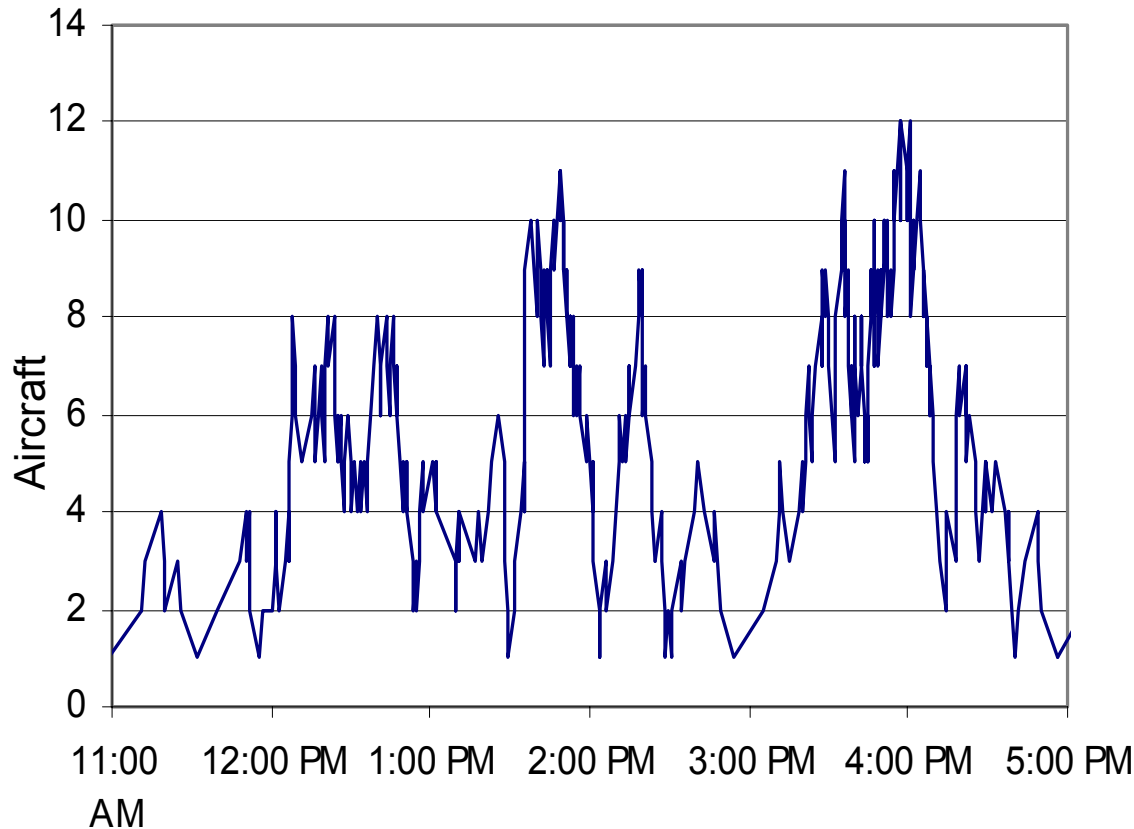
- 95th percentile delay for high-priority messages of 192 application bits or less shall be less than 1 second
- 99.9th percentile delay for high priority messages of 192 application bits or less shall be less than 5 seconds

Represents an implementation with 1 VDL channel per sector.

Simulation includes all aircraft within a busy sector.



Sector-Based Flights



Uses flight data
from 12:00 PM to
4:00 PM

155 total aircraft
during the simulated
4-hour simulation

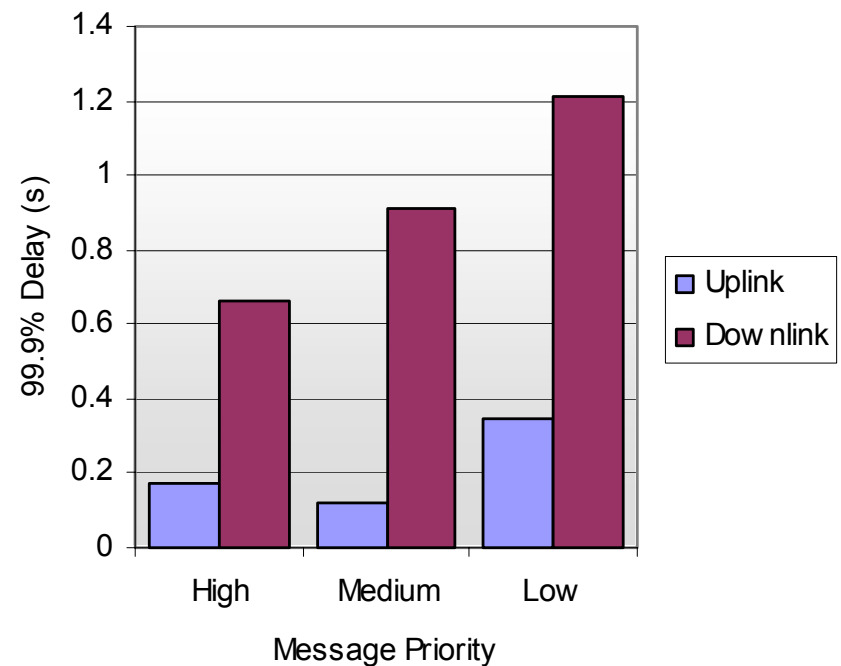
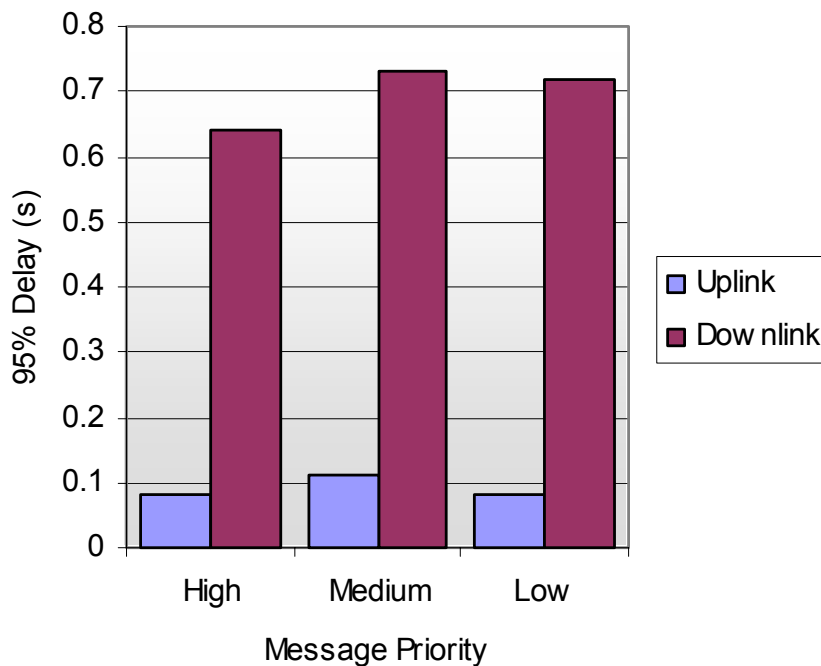
Area contains up to
12 aircraft at a time

Sent a total of 584 CPDLC messages

95th and 99.9th percentile delays are within limits

Low loading on VDL Mode 3 subnetwork

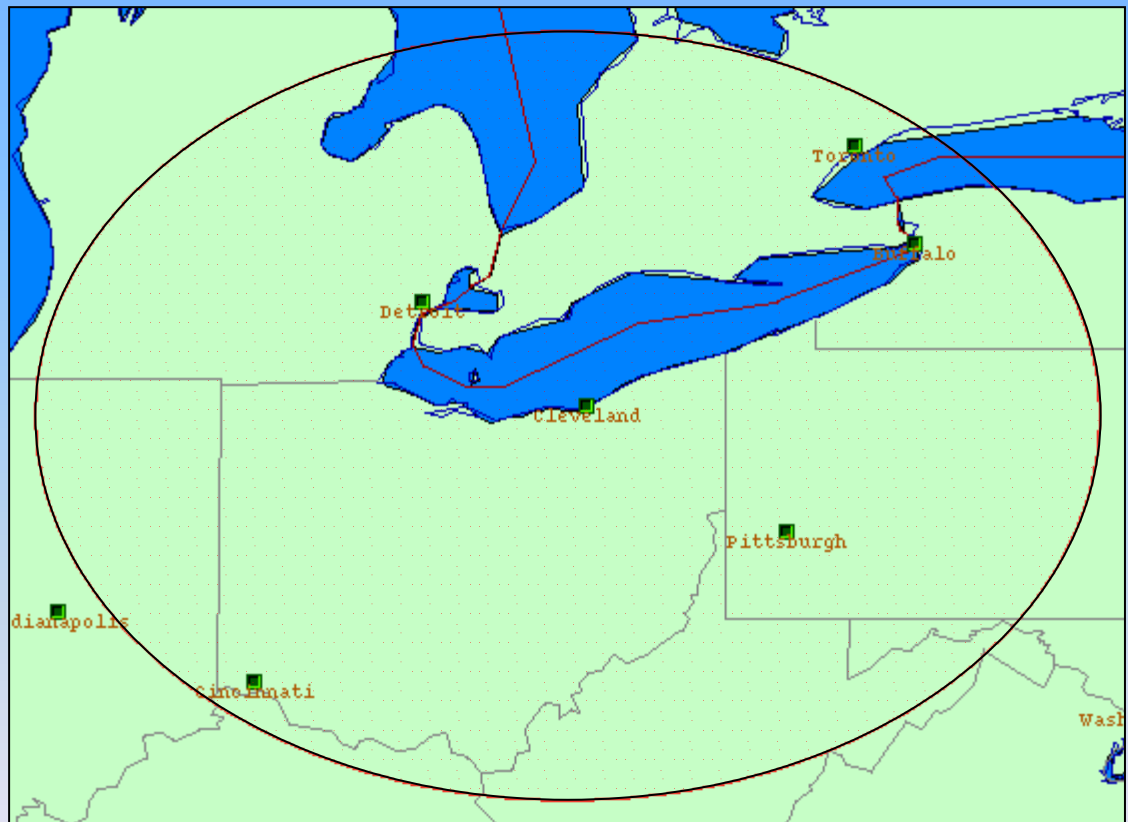
Downlink delays much higher than the uplink delays



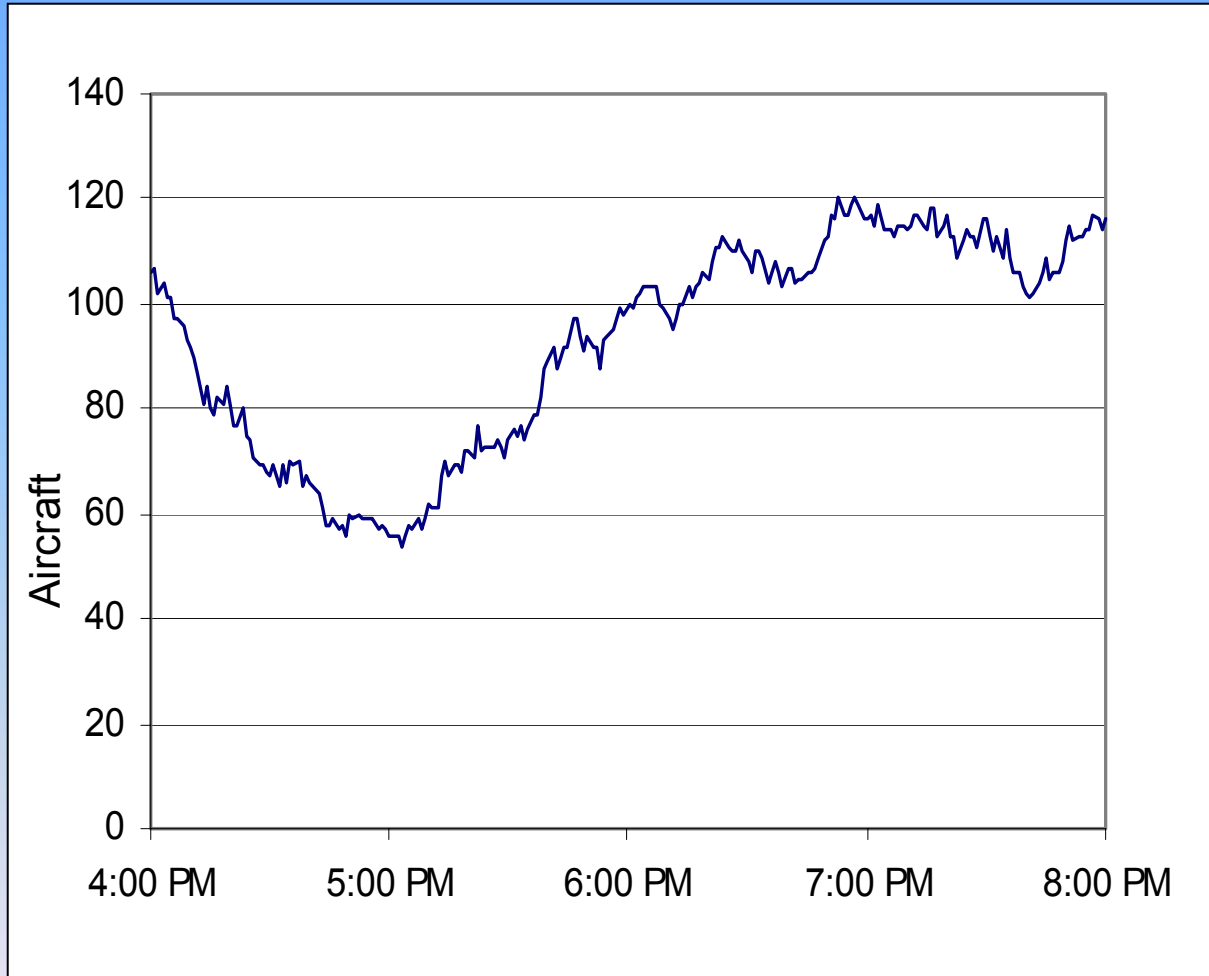
Represents an implementation with multiple sectors per channel resulting in denser traffic load

Simulation includes all aircraft within range of the ground station (up to 200 nmi) that pass through ZOB

Coverage area includes parts of adjoining ARTCCs



Range-Based Flights



Uses flight data
from 5:00 PM to
7:00 PM

297 total aircraft
during the simulated
2-hour period

Area contains up to
120 aircraft at a
time

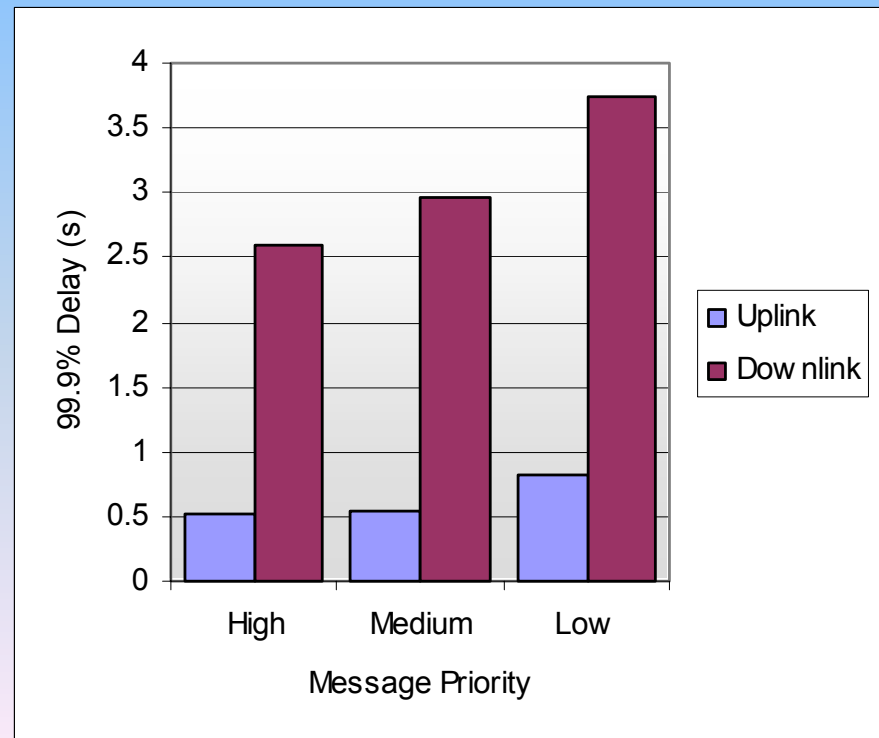
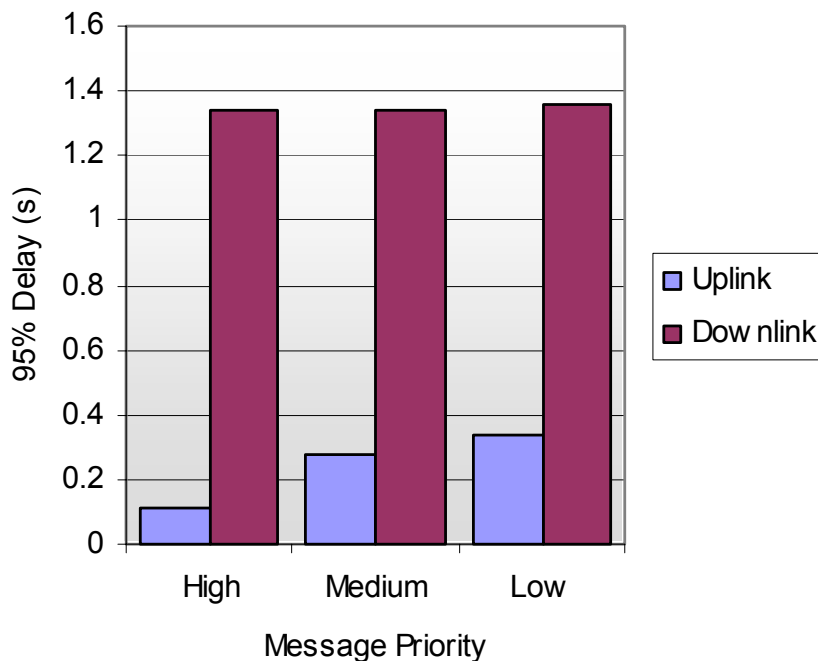
Range-Based Results

Sent a total of 4590 CPDLC messages

95th percentile downlink delay is above limit

All other delays within limits

3T could not support the entire area, possibly support several sectors



VDL Mode 3 3T can be used to handle CPDLC traffic for a single sector

- Advantage: Provides voice and data communications
- Disadvantage: Will not reduce the total number of VHF frequencies required in the NAS

VDL Mode 3 3T could support more than 1 sector

- Advantage: Reduces spectrum congestion in the current system
- Disadvantage: Requires several sectors to share a single voice channel

Other configurations provide other possibilities

Perform CPDLC simulations with other VDL Mode 3 configurations

- 2V2D
- 3V1D